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(54) IMPROVEMENTS IN AND RELATING TO APPARATUS FOR MOVING ALONG OR THROUGH A MATERIAL

(71) We, NATIONAL RESEARCH DEVELOPMENT CORPORATION, a British Corporation, established by Statute, of Kingsgate House, 66-74 Victoria Street, London, S.W.1, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to apparatus for moving along or through a material e.g. the ground or like materials.

According to the present invention, an apparatus for moving along or through a material comprises a first part with an eltctrically conductive outer surface for engagement with the material, a second part having an electrically conductive outer surface which is electrically insulated from that of the first part and for engagement with the material, the two conductive outer surfaces being connectable with a source of potential difference, and thrust means for exerting a force between the two parts to move them closer together or further apart as the case may be.

In one embodiment of the invention the first part is divided into a number of electrically insulated sections.

Conveniently the apparatus includes wall structures in the first and second parts to prevent liquid which has collected in the first part during operation of the apparatus from entering the second part and vice versa.

The apparatus may, for example, be embodied in a telescopic mole, a soft ground tunnelling machine, a remote control device for operating in a nuclear environment, other remote control devices, or a device for travelling in animal intestines. Alternatively the first and second parts are provided by the pipe sections in a pipe jacking system.

The invention also includes a method of operating an apparatus according to the present invention, the method comprising the steps of making one of said two parts cathodic and the other of said two parts anodic, and exerting a force between said two parts to move them apart, at least the majority of the relative motion between the two parts being provided by motion of the cathodic part.

The method may also include the additional subsequent steps of making said one part anodic, said other part cathodic, and exerting a force between said two parts to move them closer together, at least the majority of the relative motion between the two parts being provided by motion of the cathodic part.

The method may include the step of forming a hole in the material by motion of the leading one of said two parts of the apparatus through the material.

When the apparatus of the present invention has the first part divided into a number of electrically insulated sections, then the method may include the additional step of switching one or more of said sections out of circuit when the first part is cathodic. The term "cathodic" in this context and throughout the Specification, including the Claims, merely means that the part referred to is to be at a lower electrical potential than the part referred to as "anodic". The "cathodic" part could, for example, be at the same local electric potential as the material along or through which the apparatus is to pass.

The apparatus and method of the present invention rely on the fact that the ease with which an electrically conductive body not carrying an electric current can pass along or through the material is increased by making the body cathodic, and reduced by making the body anodic.

An embodiment of the invention will

now be described, by way of example, with reference to the three diagrammatic Figures of the accompanying drawing of which:—

Figure 1 shows a side view, partly in section, of a machine according to the present invention;

Figure 2 shows a vertical section of a modified version of the machine;

Figure 3 shows the invention as applied to a pipe-jacking technique.

Thus referring first to Figure 1, a telescopic mole 10 according to the present invention is arranged to travel in a direction *A* forming as it proceeds a hole 14 in clay soil 15. A nose portion 16 of the mole is connected with a body portion 18 by an electrically insulating bellows 20. Mole 10 is a small diameter (six inch) machine intended for cable laying purposes and capable of forming its own hole in the ground as it moves along.

Although in principle the diameter of the cylindrical portion of a machine according to the present invention can range from one inch or less to ten feet or more, if the machine is to force its way through the ground, as in the case illustrated, then the diameter of the machine is kept small (typically around six inches or so). Such a machine can for example be employed for laying underground cables (as in the present case), the cable being attached to the rear end of the machine so that the machine pulls the cable into the hole after it. If the machine is to be moved along a preformed hole in the ground, on the other hand, then obviously a similarly proportioned machine must be used if it is to grip the walls of the hole. Because in such cases the resistance to motion is so much smaller, it is possible to use much larger diameter machines.

Irrespective of the diameter of the machine, in most cases the overall length of the machine with bellows 20 contracted will preferably be roughly three times the machine diameter.

Returning to the small diameter mole shown in Figure 1, an electrical or hydraulic jack 22, of, say, 1 tonne jacking power, is connected between portions 16 and 18 but is electrically insulated from them. Jack 22 is fed from an appropriate power supply (not shown) and portions 16 and 18 are connected up with an external source of 100 volt P.D. (not shown). When it is desired to progress the machine along the hole and through the ground, the P.D. source is switched to make nose portion 16 cathodic at ground potential and body portion 18 anodic at plus 100 volts. Due to the effect already described the cathodic action of nose portion 16 facilitates its travel over the walls of hole 14 and further into clay 15. At the same time the anodic action of body portion 18 has the effect of increasing the resistance to motion of body portion 18 over the walls of hole 14. Jack 22 is now expanded and as a consequence of their differing resistances to motion the body portion 18 will remain substantially unmoved whereas nose portion 16 will move relatively easily to a new position 16′ pushing aside the clay soil as it proceeds. The polarities of portions 16, 18 are now reversed and with nose portion 16 now providing the principal resistance to motion over the walls of the hole (in position 16′), jack 22 is contracted to move body portion 18 towards nose portion 16 so that the two portions are together again in readiness for the next forward stroke in direction *A*.

In an alternative version, shown in Figure 2, the nose portion is segmented. Figure 2 shows a vertical section through the modified nose portion of this version omitting the jack and the electrical connections etc.

As will be seen from Figure 2, the nose portion is divided into eight sections 101-108 each electrically insulated from its neighbours by insulation strips such as strip 109 and separately connected to an external switching system (not shown) which can either switch it out of circuit altogether so that it carries no electric current, or else switch it to the negative (earth potential) side of the P.D. source to make the section concerned cathodic.

The general constructional and operational details of the machine are as described with reference to the Figure 1 embodiment, the nose portion alternately assuming an overall cathode potential and an overall anode potential as the machine works its way through the ground. Corresponding reference numerals have been used for corresponding parts of the two embodiments. The essential difference between the two embodiments is that in the Figure 2 embodiment the machine can be steered by switching out some of the nose portion segments instead of switching them to cathode potential during the "nose cathodic" part of the cycle. The switched out sections will experience a greater resistance to motion through the ground than the cathodic sections and this will cause the nose portion to pull towards the side of the switched out sections as jack 22 is expanded. Thus if say sections 101-4 are switched out when sections 105-8 are cathodic, the nose portion of the machine will move forwardly and upwardly when jack 22 is expanded. During the subsequent "nose anodic" part of the cycle, it is obviously better to have *all* sections 101-8 anodic.

If, when the Figure 2 machine has been upwardly orientated in the way above de-

scribed, *all* the nose portion sections are made cathodic during that part of the cycle, the machine will continue in its new direction. To level off the machine again, the bottom four sections are switched out during the "nose cathodic" phase and the greater resistance to motion then experienced by these bottom sections will pull the nose portion down until the machine is again disposed horizontally.

Obviously the amount of turn at any given stage can be reduced by switching out a lesser number of sections. It will also be appreciated that the machine can be steered to right or to left or in any intermediate direction by an appropriate choice of the nose sections to be switched out. An alternative method of steering might be to reduce the cathode potential of particular nose sections instead of switching them out.

In both the embodiments so far described, it is of course most important that the nose and body portions of the machine should not be short circuited by water which has collected within the machine when it is horizontally disposed e.g. as might occur when the machine is moving through a water-laden material such as a clay soil. To prevent this happening, either the machine is completely sealed (a solution usually confined to the case where the machine is a small diameter machine) or else (as in the case illustrated) adjacent ends of the nose and body portions of the machine are provided with walls (124, 126) to confine the trapped water to two separated pools (128, 130). Water is continuously or periodically pumped out from these pools to ensure that it never accumulates to a depth at which it can flow over the tops of the walls.

Figure 3 illustrates a pipe jacking arrangement in accordance with the present invention and in which 12 inch diameter rings are being jacked into the ground from a pit 30. In essence the arrangement includes a principal hydraulic jack 32 for exerting a force between the outermost ring (34) and a back-up assembly (36) in the pit, and an electrically insulated auxiliary hydraulic jack 38 acting between the innermost ring (40) and the preceding ring (42). The jacks are connected up with a suitable power source (not shown) and the rings 34, 40, 42 with a source of 200 volts potential difference (not shown). Typically for a 12 inch diameter pipe, the required jacking forces would range from three tonnes up to ten tonnes for a closed end tube 40 to two tonnes up to four tonnes for an open ended tube 40 (the case shown in Figure 3) the particular value in any given case depending principally on the type of soil involved.

In order to progress the pipe in direction *B* through clay soil 44 the P.D. source is switched to make ring 40 cathodic (earth potential), and rings 34, 42 anodic (+ 200 volts). Jack 38 is then expanded and for the same reasons as those already discussed in relation to the Figure 1 embodiment, rings 34, 42 will grip the soil and remain stationary whereas ring 40 will be pushed further into the ground in direction *B*.

When ring 40 has been progressed by one ring length (measured in direction *B*), the P.D. source is switched to make ring 40 anodic and the other rings cathodic. Jack 32 is now expanded to push rings 34, 42 through the ground, jack 38 being simultaneously contracted to allow or encourage this movement. When rings 34, 42 have been moved as far as they will go, then ram 32 is retracted, a new ring inserted in the position occupied in Figure 2 by ring 34, and the process repeated. Removal of earth from within the rings as they progress through the ground will be done manually or mechanically as with conventional pipe jacking techniques. Water is removed using conventional pumping techniques.

It will be appreciated that in the Figure 3 embodiment, the "first part" referred to in the most general statements of the present invention will be provided first by one ring (42), then by two (42 and 34), then by three etc.

Although only a few examples of the invention have been described above, it will be clear that the present invention is equally applicable to any other case in which it is desired to move parts through a passage or material or along the surface of a material capable of supporting electro-osmotic effects. The terminology 'ground or like material' is intended to embrace all such materials and it includes specifically fine-grained clay like soils and like materials permeated with an electrically conducting liquid.

,WHAT WE CLAIM IS:—

1. An apparatus for moving along or through a material comprising a first part with an electrically conductive outer surface for engagement with the material, a second part having an electrically conductive outer surface which is electrically insulated from that of the first part and for engagement with the material, the two conductive outer surfaces being connectible with a source of potential difference, and thrust means for exerting a force between the two parts to move them closer together or further apart as the case may be.

2. An apparatus as claimed in Claim 1 in which the first part is divided into a number of electrically insulated sections.

3. An apparatus as claimed in Claim 1 or Claim 2 including wall structures in the first and second parts to prevent liquid which has collected in the first part during operation of the apparatus from entering the second part and vice versa.

4. A telescopic mole, a soft ground tunneiling machine, a remote control device for operating in a nuclear or other environment, or a device for travelling in animal intestines comprising apparatus as claimed in any preceding claim.

5. An apparatus as claimed in Claim 1 in which the first and second parts are provided by the pipe sections in a pipe jacking system.

6. An apparatus as claimed in Claim 1 and substantially as hereinbefore described with reference to, and as illustrated in, Figure 1 or Figure 2 or Figure 3 of the accompanying drawing.

7. A method of operating an apparatus according to any of Claims 1 to 6, the method comprising the steps of making one of said two parts cathodic (as hereinbefore defined) and the other of said two parts anodic, and exerting a force between said two parts to move them apart, at least the majority of the relative motion between the two parts being provided by motion of the cathodic part.

8. A method as claimed in Claim 7 including the additional subsequent steps of making said one part anodic, said other part cathodic, and exerting a force between said two parts to move them closer together, at least the majority of the relative motion between the two parts being provided by motion of the cathodic part.

9. A method as claimed in Claim 7 or Claim 8 including the step of forming a hole in the material by motion of the leading one of said two parts of the apparatus through the material.

10. A method as claimed in any of Claims 7 to 9 when the apparatus incorporates the limitations of Claim 2, the method including the additional step of switching one or more of said sections out of circuit when the first part is cathodic.

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1 418 492 COMPLETE SPECIFICATION
1 SHEET This drawing is a reproduction of the Original on a reduced scale.

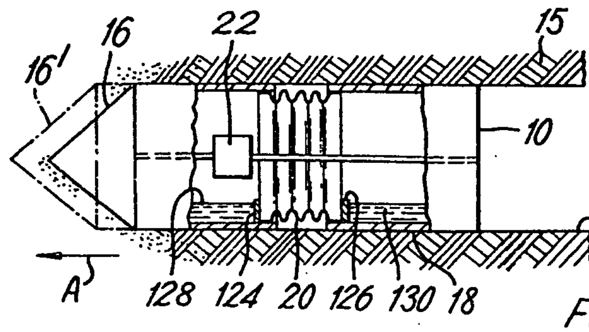

Fig. 1

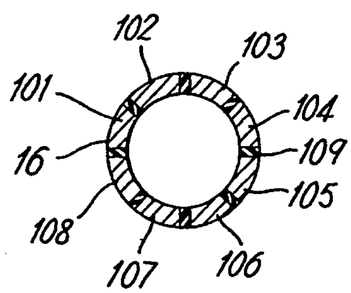

Fig. 2

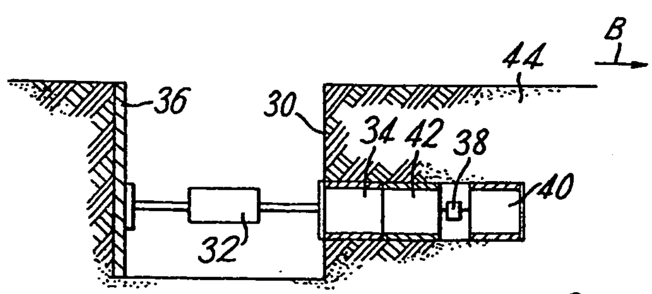

Fig. 3